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**Special Technical Report  
11/17/92**

**Field Emitter Array RF Amplifier Development Project  
Phase one, Cathode Technology Development  
DARPA Contract #MDA 972-91-C-0028**

**Sponsored by:  
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DARPA/DSO**

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**Acting Principal Investigator : C T. Sune**

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**Special Technical Report  
11/17/92**

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**Contractor :**

**MCNC, Center for Microelectronic  
Systems Technologies  
Post Office Box 12889  
Research Triangle Park, NC 27709**

**Effective Date of Contract : 9/09/91**

**Contract Expiration Date: 3/09/93**

**Contract Amount: Basic \$1,178,466.00**

**Acting Principal Investigator: C T. Sune**

**919-248-1975, Fax: 919-248-1455**

**Title of Work : Field Emitter Array RF Amplifier  
Development Project  
Phase one, Cathode Technology  
Development**

**DARPA Contract #MDA 972-91-C-0028**

**Field Emitter Array RF Amplifier Development Project  
Phase one, Cathode Technology Development  
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**Objective : RF modulation of gated column silicon field emitter with diamond coated**

## **I. Introduction**

The initial RF modulation testing of the gated column silicon field emitter with a diamond coated has been done. The set-up of the testing is as shown in Fig. 1. It should be noted that we didn't use 50 ohm coaxial cable inside the vacuum chamber for this testing since the configuration was initially used for DC testing, and we wanted to get earlier AC results at this time. It is well known the mismatch of the circuit will give a lot of loss during the RF measuring. This report completes modulation at 0.36 GHz, and even higher performance is expected after full blown AC testing.

## **II Testing results**

### **DC testing:**

Fig. 2a shows the DC characteristics of this device (5x5 array) on a linear scale while Fig. 2b shows the Fowler-Nordheim plot of the measured data. Fig. 3a and 3b show the SEM pictures of this devices for single and array field emitters respectively.

### **RF modulation:**

Fig. 4a shows the carrier signal at 0.36 GHz. Fig. 4b shows the RF modulation of device biased at  $V_g=70V$ ,  $V_a = 250V$ ,  $I_a < 1$  nA Fig. 4c shows the RF modulation of device biased at  $V_g=112V$ ,  $V_a = 250V$ ,  $I_a = 2.0$   $\mu A$

## **III. Discussions**

The DC characteristic, as shown in Fig. 2, of this device is comparable to what we reported from the standard silicon field emitter ( 2  $\mu m$  opening at gate and 1  $\mu m$  height, tip radius is about 100  $\text{\AA}$ ). From Fig. 3, the gate opening is about 2.26  $\mu m$ , the tip is 1  $\mu m$  below the bottom of gate electrode, and the tip radius is more than 600  $\text{\AA}$ ). The diamond-like film was coated on the silicon tips by remote plasma diamond-like film deposition techniques with a short sputtering etching before deposition and to a thickness of approximate 100  $\text{\AA}$ . The effect of diamond coating on the emission characteristic of the silicon field emitter is pronounced since much larger radius of the tip of this device than that of the standard device was observed from the devices shown in Fig. 3, while

this diamond coated device still has comparable electron emission characteristics.

From the results of Fig. 4, it is noted that even without a matching circuit inside the vacuum chamber, we still can get the RF modulation up to 0.36 GHz. No testing was done at frequency above 0.36 GHz. Compare the amplitude of the signal of Figs. 4b (device is barely turned on) and 4c (device is emitting about 2  $\mu$ A electrons), it is found that this device responds with positive voltage gain at least up to 0.36 GHz without a matching circuit inside the vacuum chamber.

In order to eliminate any mismatch in the measurement, the configuration of RF testing (Fig. 5) has been proposed. The connections will be 50 ohm coaxial cables and be as close as possible to the device. The high voltage chip capacitor will be used at the input and the output to isolate the RF and DC signal. The input signal will be connected to the oscilloscope as a reference for comparison. The network analyzer will be used to measure S-parameters. The required parts have been ordered and we plan to do RF testing in a couple of weeks. The device is packaged on the ceramic DIP package now, but the microwave package will be used eventually.

#### **IV. Conclusions**

The devices were fabricated at MCNC, even without a matching circuit inside the vacuum chamber, performs the RF modulation up to 0.36 GHz, and even higher performance is expected after full AC testing with RF testing set-up.

### Figure Captions

Fig. 1 Initial testing set-up for DC & RF testing.

Fig. 2a DC characteristics of this device (5x5 array) on a linear scale.

Fig. 2b The Fowler-Nordheim plot of the measured data.

Fig. 3 SEM pictures of this devices for single and array field emitters respectively.

Fig. 4a The carrier signal at 0.36 GHz.

Fig. 4b The RF modulation of device biased at  $V_g=70V$ ,  $V_a = 250V$ ,  $I_a < 1 \text{ nA}$

Fig. 4c The RF modulation of device biased at  $V_g=112V$ ,  $V_a = 250V$ ,  $I_a = 2.0 \mu A$

Fig. 5 Proposed RF testing set-up.

**FIG. 1**  
**Initial Configuration of RF Testing**

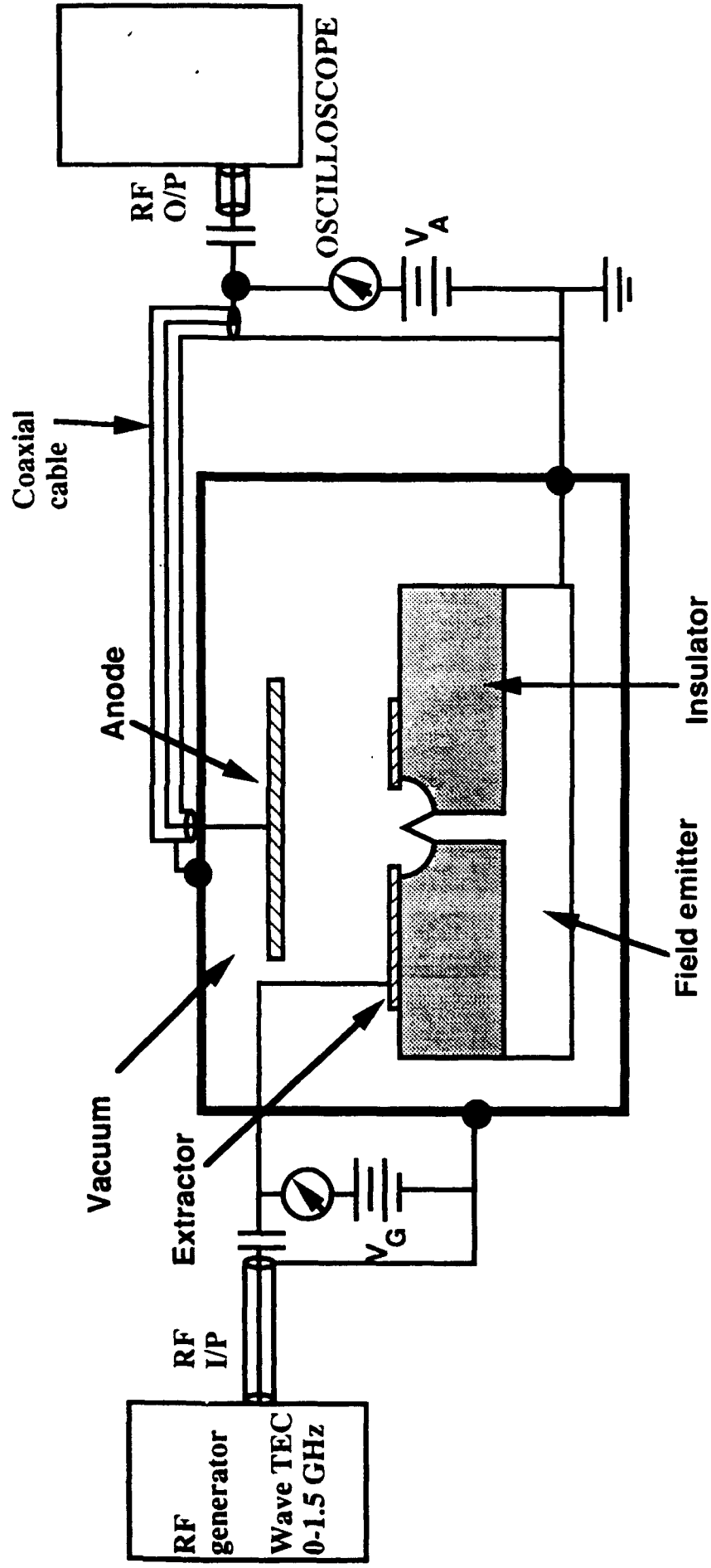


Fig. 2a

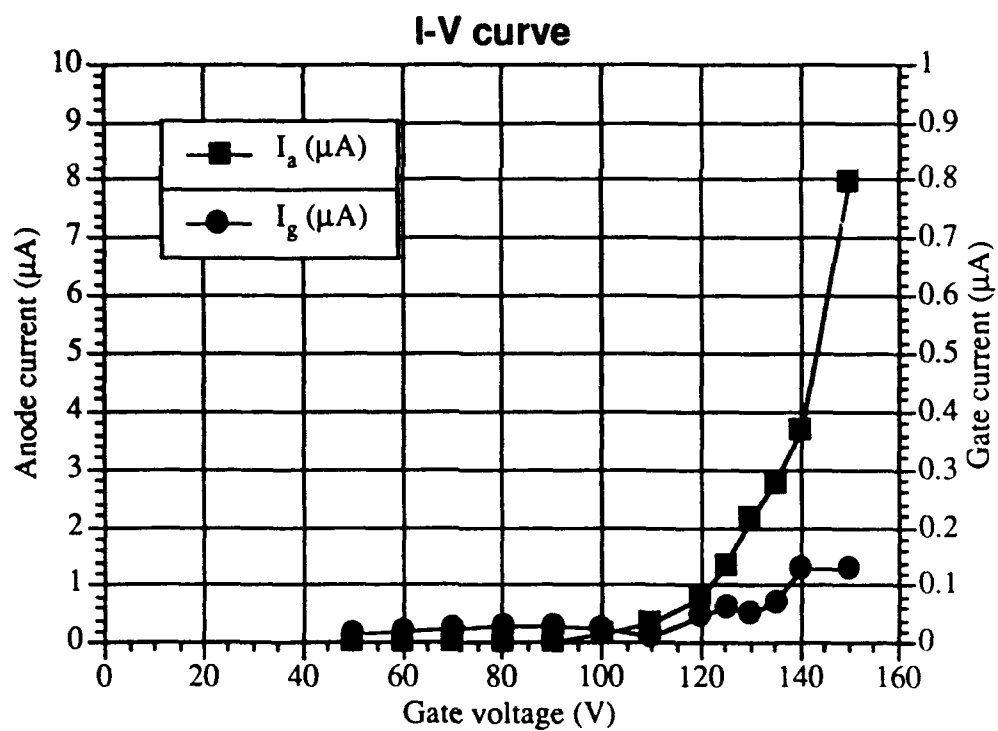


Fig. 2b

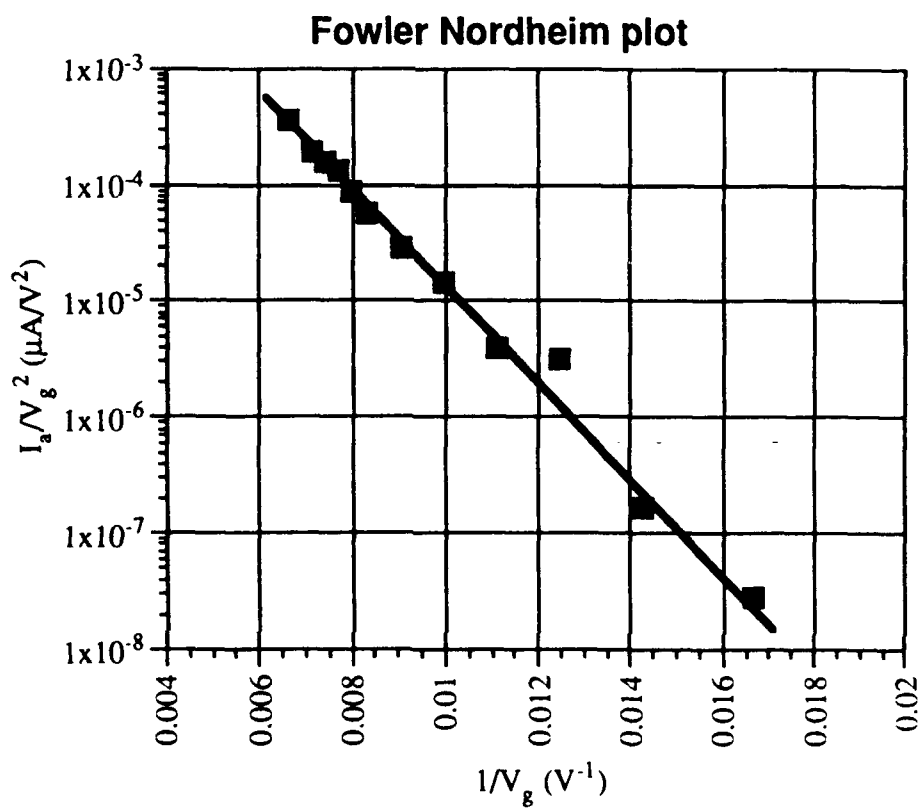


Fig. 3a.



Fig. 3b.

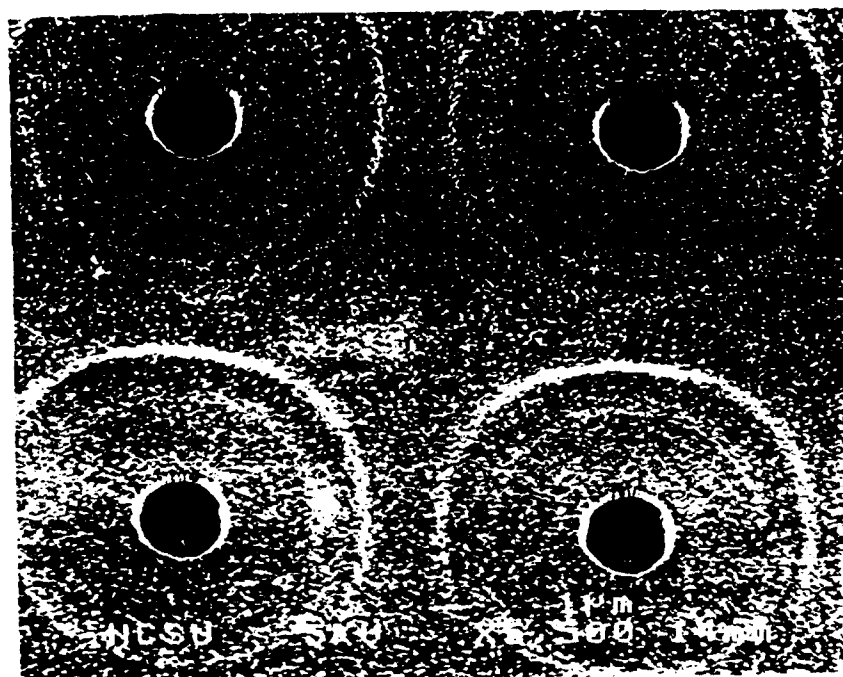




Fig. 4a.

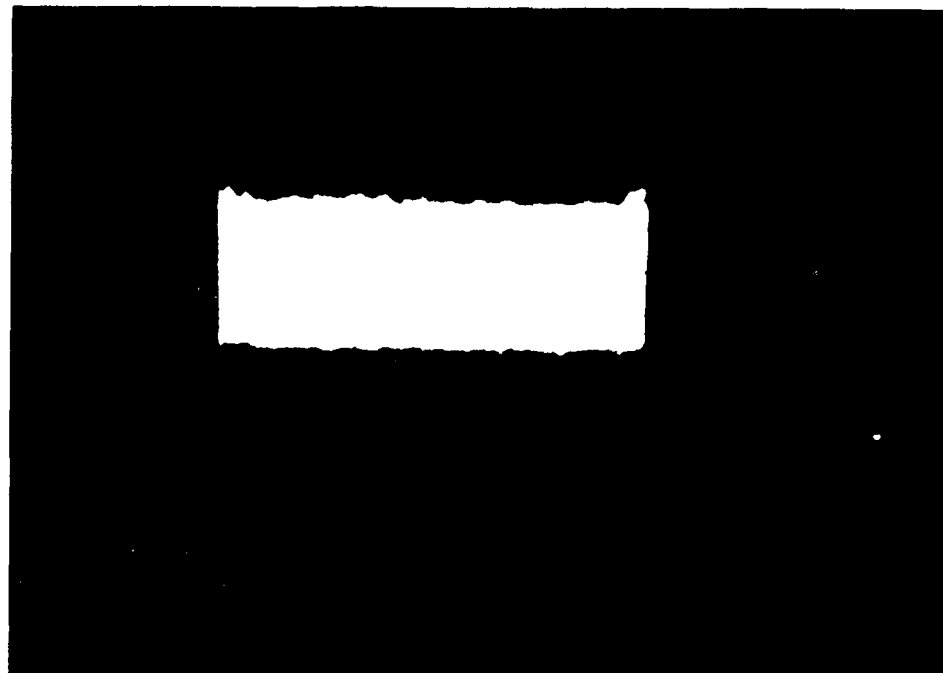


Fig. 4b.

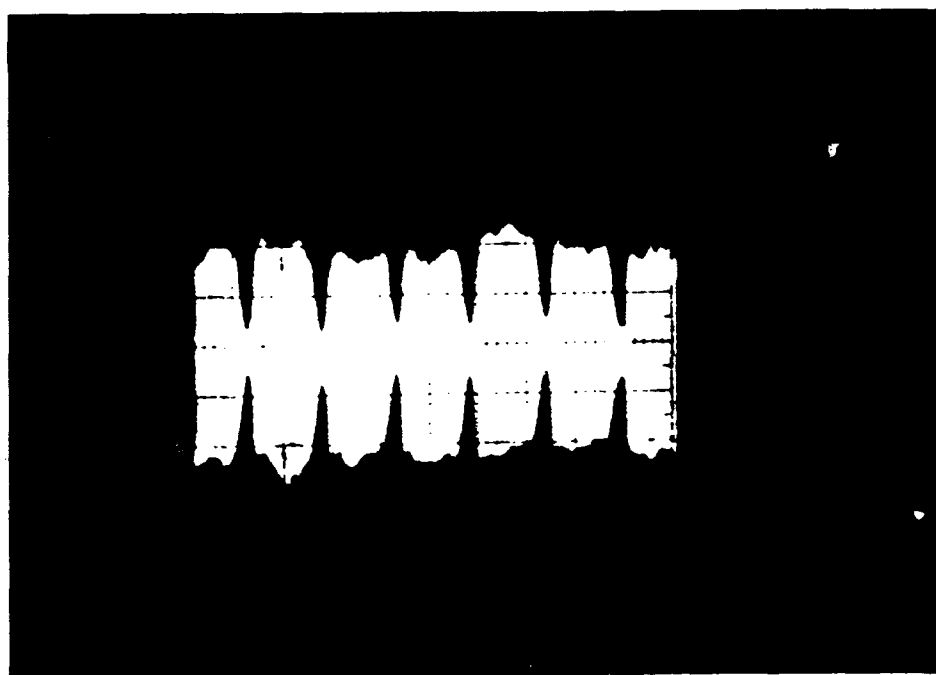
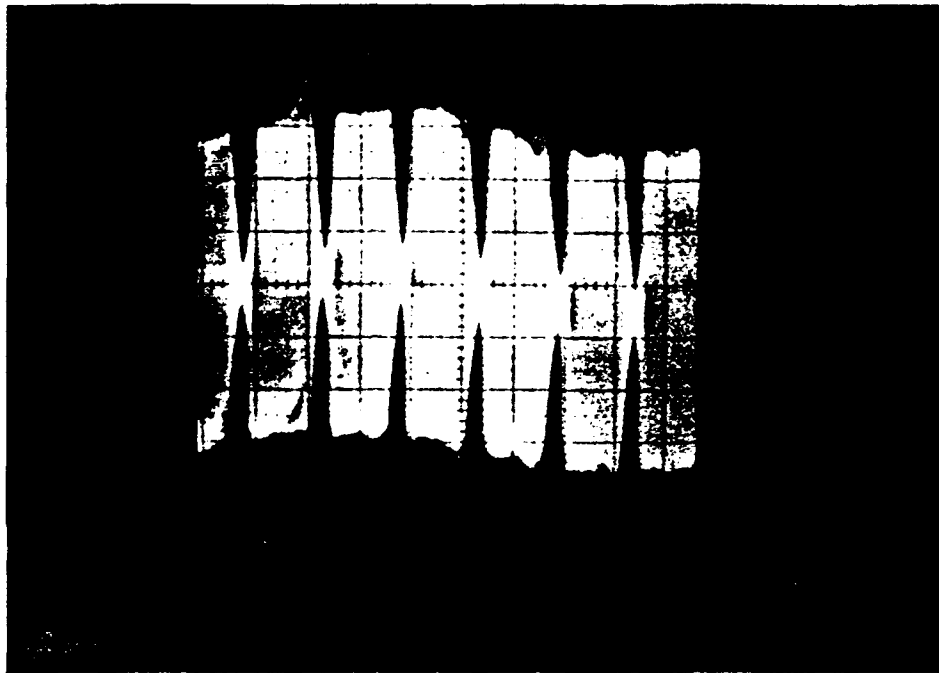


Fig. 4c.



# FIG. 5 Proposed Configuration of RF Testing

